Smart Parking Management System

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ABSTRACT: The growing population of people living in cities, along with the desire to enhance citizen's living standards, has prompted government agencies, companies, and lawmakers to embrace the smart-city idea. Despite the fact that there is no universal term of a smart city, the Union has suggested a set of metrics to assess the city's smartness. In contemporary cities, parking control systems are important because they decrease traffic-related pollution levels, improve revenue for businesses that handle parking spots, and so on. We offer an IoT-based carpark monitoring system in this article. A magneto-resistive sensor for vehicle identification and a channel for providing the current location of parking spaces to the end-user make up the system. As a proof of concept, a protected sample system was introduced utilizing a microcontroller and a Zigbee module. Our method is extremely dependable, and the results indicate that it could be utilised to categorize vehicle models.

KEYWORDS: Intelligent Parking, Parking Management, Smart City, Smart Parking, Vehicle Occupancy Management.

1. INTRODUCTION

The smart traffic system is a potential technology for addressing transportation issues like congestion, accident, pollution, etc [1]. Smart transport systems allow intelligent movement under the smart-city concept. An intelligent traffic control system is an important component of a balanced and environment friendly transport solution. Parking management in highly crowded cities, as mentioned in few papers, is a significant barrier since motorists may spend time searching for a vacant parking spot [2], [3]. There are approximately 15 million parking spots in Asia. Additionally, a disgruntled driver may park illegally, causing traffic congestion and possibly blocking other motorists.

An intelligent traffic monitoring system has been suggested to solve the issue of parking in highly populated regions [4], [5]. In general, the suggested systems may be classified either as invasive or non-invasive, and deductive approach, weigh-in-motion, infrared sensors, and other intrusive devices are used. Cameras, LIDAR, microphone arrays, hydraulic roadway tunnels, and piezo-cables were some of the non-invasive technologies.

We present an IoT-based intelligent vehicle monitoring system in this study. The remainder of the work is laid out as follows. We address related work in literature review section. Next section lays forth the theoretical basis for the automobile detecting sensor that uses the earth's electromagnetic field, as well as the detection techniques and suggested design. Further, in a later section, we discuss the methodology and the last section brings the paper to a conclusion.

2. LITERATURE REVIEW

The Sifuentes et al. suggested a magneto-resistive detector activated by an optic sensing device to decrease the magneto-resistive sensor's energy usage [6]. The system design is made up of a microcontroller, an analogue magnetic sensor, an optic sensor, and a Zigbee transceiver. The suggested method has resulted in a very large reduction in electric usage. Security and dependability concerns, on the other hand, just haven't been addressed, particularly if the equipment is to function in the darkness at nighttimes.

Farhad et al. suggested an IoT-based vehicle park management system [7]. Several kinds of sensors are used to determine space occupancy: magneto-resistive, lighting, and heat. The sensor nodes detect if the car park space is occupied and send the information to a network gateway using the online data transmission. The signal from the various detectors is received by an online server, which then shows the occupancy state through a mobile app. While the researchers demonstrated that the technology is 98 percent effective in determining the car park occupancy in the experiment, protection and energy usage were not taken into account.

3. DISCUSSION

3.1. Sensor based on magnetic fields:

Steel, alloys as well as few other elements are used to build automobiles. The amount of material used is determined by the type of automobile, year of manufacture, and carmaker. Aluminium, fibre, and steel and some alloys are some of the most often utilized materials in car components.

In the realm of public transport, magnetism has been used extensively in a variety of situations. Magnetic-based sensors have been used in the control of traffic congestion for two primary purposes. One of the sensors is a magnetometer, which detects the electromagnetic field generated by a vehicle on the road. It includes for example a hall-effect and fluxgate sensors. Further, since most modern cars have got a minimal electromagnetic footprint, this kind of detector is no longer appropriate. The Anisotropic Magneto-Resistive (AMR) sensing unit, which detects our planet's magnetic field, is the next type of sensor used.

AMR sensors use an operational amplifier to transform the magnetic field strength into a low-voltage electric signal. The electromagnetic field of the planet is a three-dimensional (3D) vector as given by the below equation.

$$\vec{B} = -\Delta V(\rho, \theta, \phi, t)$$

Where,

V (ρ, θ, φ, t) is magnetic scalar potential.

In spherical coordinate system, it is given by equation as shown below.

$$V(\rho, \theta, \phi, t) = a \sum_{n=1}^{N} \sum_{k=0}^{n} \left(\frac{a}{\rho}\right)^{n+1} \times \left[g_n^k(t)\cos(k\phi) + h_n^k(t)\sin(k\phi) + p_n^k(t)\cos(\theta)\right]$$

Where,

θ is the co-latitude geocentric,

ρ is distance from earth's center,

φ is longitude in the east,

gk n(t) and hk n(t) are the Gauss coefficient, and

pk n(t) cos(θ) are the quasi-normalized Schmidt functions of order k and degree n.

In the Cartesian space (x, y, z), the Earth gravitational flux typically includes three constituents. The following equations show the transition from the coordinate system to the Cartesian space.

$$x = \rho \sin \theta \cos \varphi,$$

$$y = \sin \theta \sin \varphi,$$

$$z = \rho \cos \theta$$

The magnetic field of earth has a relatively low intensity i.e. only a few Gauss. The optimal techniques are needed to calculate the magnetic field of the planet earth that might include elevation, longitude, and latitude etc. The strength of the magnetic field in some cities can be seen in Table 1. The disruption of the magnetic field of earth is measured in order to recognise the automobile employing an AMR detector. The impact of earth's magnetic field on an automobile is shown in Figure 1.

Table 1: In certain towns, the magnetic field of the Earth is calculated and shown below.

City (Country)	B_x (Gauss)	B_y (Gauss)	B_z (Gauss)	B (Gauss)
Buraidah (KSA)	0.277	-0.07	0.253	0.289
Makkah (KSA)	0.347	0.020	0.208	0.406
Stockholm (Sweden)	0.150	0.015	0.48	0.5

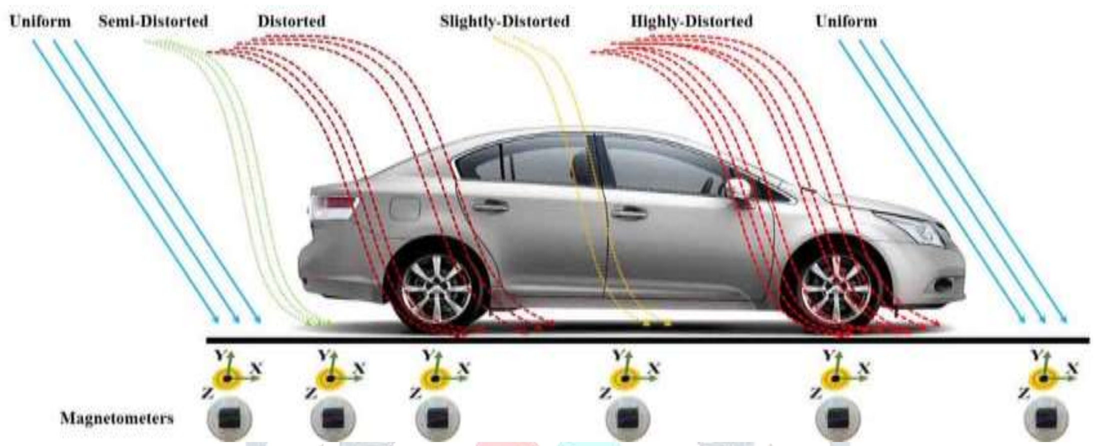

Figure 1: Illustrates the magnetic field of the earth that is affected by the metal component of the vehicle [8]**.**

3.2. Architecture of the System:

The suggested system is built around an AMR-based system. A microprocessor device for analyzing AMR information and a transmitter for sending brief instructions wirelessly make up the whole system. Such signals are sent to boundary gateways, which converts them and connects the sensing devices to the World Wide Web (WWW). The suggested mechanism is shown in Figure 2. The entry point gateway serves as a link amongst the Wi-Fi module utilized by the system and the Internet's IP-based infrastructure. Due of its resource economy and low bandwidth usage, the model employs the Message Queuing Telemetry Transport (MQTT) protocol to transmit data via IP. It is a compact telecommunication standard designed specifically for Internet of Things (IoT) deployments. It adopts the pattern of a publisher and a consumer. As a result, it provides a more decoupled and stable network than those of other IoT-based technologies like XMPP and CoAP. The publisher-consumer design also provides a much more robust solution which would accommodate a large number of nodes. It has a brokerage element, which accepts communications by publications and distributes it among subscribers. Devices serve as publications in the proposed approach, delivering data to the broker through gateways. The broker is deployed on a cloud-based server. It offers an interface allowing ultimate users to connect to and obtain data. This design separates data publishers from customers, providing for more robustness and adaptability.

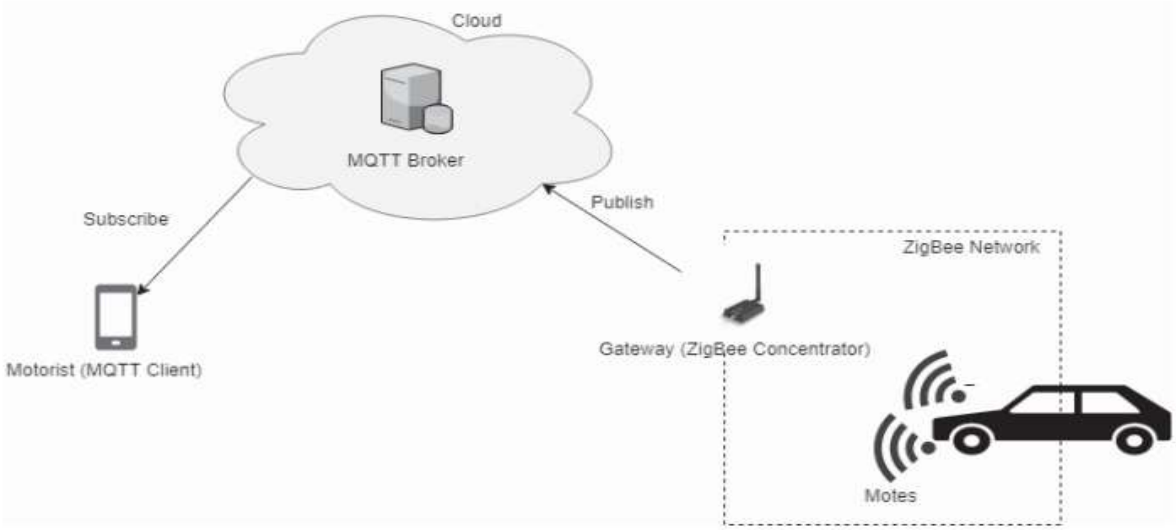

Figure 2: Illustrating the suggested mechanism of the System architecture.

Table 2: Illustrates the comparison of the most important IoT transmission standards [9]**.**

Technology	Frequency	Data Rate	Range	Power Usage	Cost
2G/3G	Cellular Bands	10 Mbps	Several Miles	High	High
Bluetooth/BLE	2.4Ghz	1, 2, 3 Mbps	~300 feet	Low	Low
802.15.4	subGhz, 2.4GHz	40, 250 kbps	> 100 square miles	Low	Low
LoRa	subGhz	< 50 kbps	1-3 miles	Low	Medium
LTE Cat 0/1	Cellular Bands	1-10 Mbps	Several Miles	Medium	High
NB-IoT	Cellular Bands	0.1-1 Mbps	Several Miles	Medium	High
SigFox	subGhz	< 1 kbps	Several Miles	Low	Medium
Weightless	subGhz	0.1-24 Mbps	Several Miles	Low	Low
Wi-Fi	subGhz, 2.4Ghz, 5Ghz	0.1-54 Mbps	< 300 feet	Medium	Low
WirelessHART	2.4Ghz	250 kbps	~300 feet	Medium	Medium
ZigBee	2.4Ghz	250 kbps	~300 feet	Low	Medium
Z-Wave	subGhz	40 kbps	~100 feet	Low	Medium

There are a variety of wireless sensor network topologies that may be utilized to transport data from the parking spot to the server. Bluetooth, Zigbee, Wi-Fi, Z-wave, etc. are some of the current IoT networking technologies. The characteristics of the abovementioned transmission systems are compared in Table 2. Data protection and radio strength are two frequent characteristics. AES is supported by all three technologies, which broadcast at 20dBm. Zigbee was selected as the cable-free transmission technology to link the detectors to WWW in our system. The mesh network design was selected to span a wide region. As illustrated in Figure 3, the system is established up of end-nodes that confirm the existence of the automobile, gateways, and a controller.

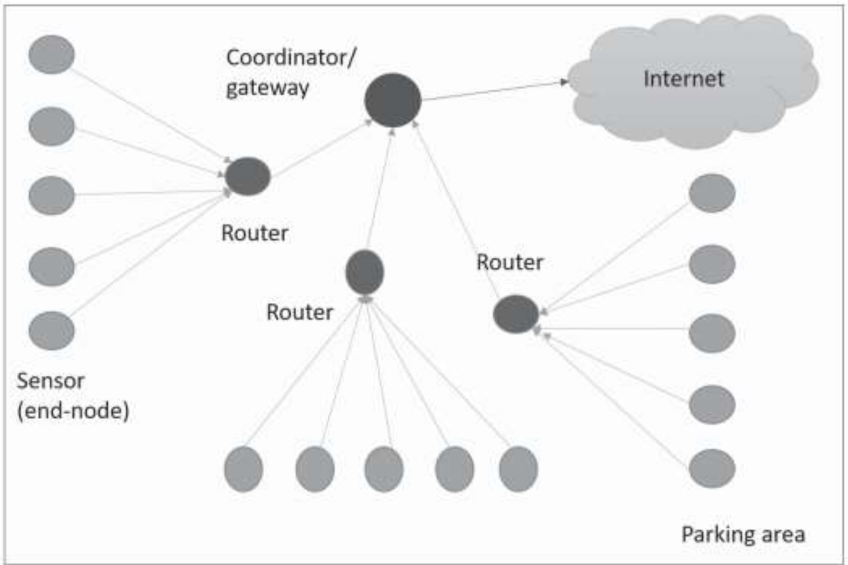

Figure 3: Illustrating the Zigbee Mesh Network [10]**.**

The end-point of our vehicle management or parking system was developed utilising LSM303DLH. A multi-axis magnetometer and speedometer are included in the LSM3030DLH. The schematic diagram of the same is shown in Figure 4.

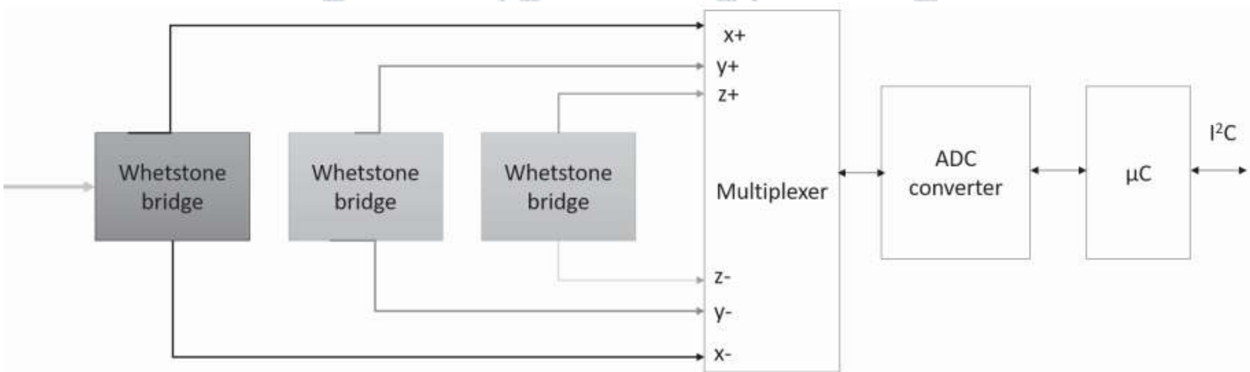

Figure 4: A block schematic of a magneto-resistive sensor with a microcontroller is shown[10]**.**

The following is how the detecting methodology performs. Whenever the parking space is vacant, the magneto-resistive monitors the magnetic field of the earth. Further, LSM3030DLH monitors the gravitational flux each 15 minutes interval to save power usage. The user has the ability to change the measurement interval. If intensity of the detected magnetic field exceeds a certain threshold, the LSM3030DLH pauses for ten minutes before measuring it and notifies the user through the Zigbee transmission standard that the space has been taken. In Algorithm 1, the pseudo-code is presented.

Algorithm 1 Vehicle detection algorithm.

procedure PARKDETECTION(τ, t_{min}, t_{sample})
  wait t_{sample}
  read B_x ,B_y, and B_y;
  $B \leftarrow \sqrt(B_x^2 + B_y^2 + B_x^2)$
  if $B > \tau$ **then**
    wait t_{min}
    read B_x ,B_y, and B_y;
    if $B > \tau$ **then**
      Occupied $\leftarrow$ true
    elseOccupied $\leftarrow$ false
    end if
  elseOccupied $\leftarrow$ false
  end if
  return Occupied
end procedure

Two Arduino, two Xbee modules, and an LSM3030DLH were used to develop the present framework. The Arduino IDE was used to create the identification method, which was then transferred to the sensors. The sensor delivers a brief communication to a MQTT server whenever an automobile is spotted. The notification includes the parking code, its geolocation, as well as the moment the car arrived the parking lot.

We performed extensive tests with different automobiles to properly establish the threshold value for earth's magnetic field.

3.3. Sensor's Position:

The disturbance to the magnetosphere, as seen in Figure 3, changes all along the car body. To find out, we performed tests wherein we measured the magnetic-field variables at three different locations. The findings, as shown in Table 3, show that the magnetic force is strongly perturbed at the rear as well as center of the automobile.

Table 3: Illustrates the intensity of magnetic field throughout the car body.

Location	Front	Rear	Middle
B (Gauss)	2.64	2.41	2.88

3.4. Forward Parking for Car Detection:

The sensor was positioned beneath the vehicle motor in first trial, with the x-axis aligned parallel to the chassis bars. The findings, as shown in Figure 5, indicate that the z-constituent of the gravitational flux is significantly altered when contrasted to the x and y constituents.

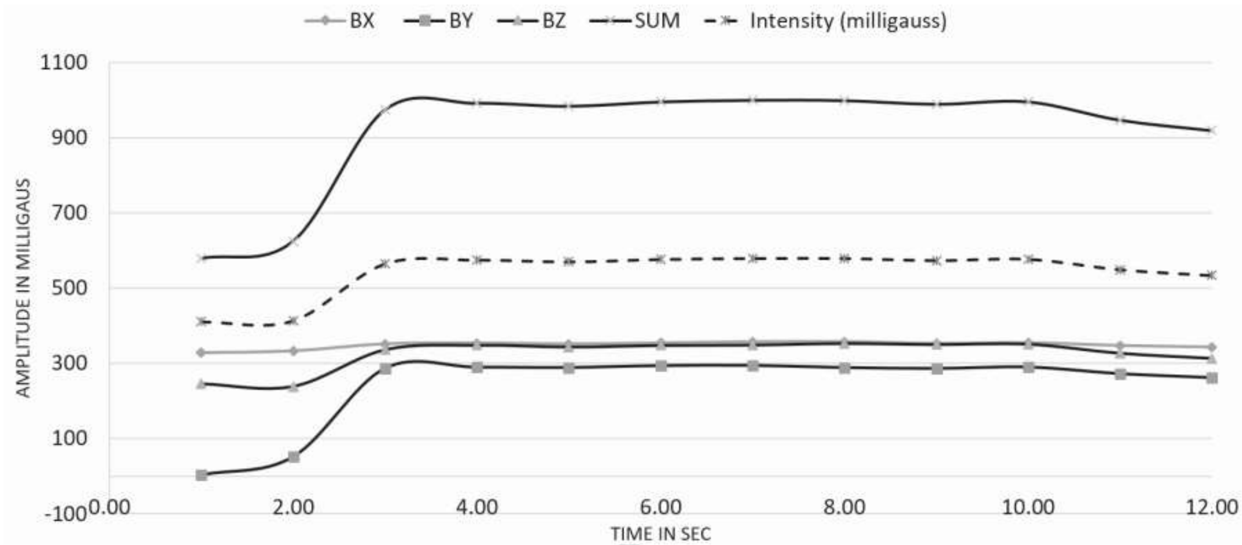

Figure 5: For parking a vehicle in forward mode, a detection profile has been created.

3.5. Backward and Forward Parking:

The sensor was put beneath a vehicle to study the characteristics of the magnetization in forward as well as in backward parking. Table 4 tabulates the data for the y-constituent of the gravitational flux. The y-axis may be used to calculate the movement orientation, according to the table.

Table 4: Tabulates x and y-constituent of backward and forward driving.

time	Fackward		Backward	
1	B_y	B_x	B_y	B_x
2	1103	2330.9	257	2386.2
3	1107	2327.37	89	2676.7
4	1105	2329.74	104	2671.42
5	1105	2329.74	100	2670.97
6	1100	2323.18	86	2668.22
7	1106	2323.73	90	2683.06
8	1109	2331.69	89	2672
9	1100	2331.6	116	2794.86
10	1100	2331.6	202	2999.31
11	1105	2338.2	346	3076.68
12	1501	2683.7	339	3091.48
13	1598	2780.1	339	3095

4. CONCLUSION

We presented an IoT-based intelligent vehicle control and parking system in this study. The proposal uses magneto-resistive technology to estimate the occupancy of a parking space by sensing the gravitational flux. The Park direction i.e., backward or forward may be detected by the system. The occupancy data is sent via the Zigbee to the online server. Our approach is extremely efficient at spotting the existence of the car and can easily distinguish backward or forward parking, according to the results of the extensive trial.

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